REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
11-11-2014	Final Report	1-Sep-2013 - 31-Aug-2014

4. TITLE AND SUBTITLE
Final Report: Network Frontier Workshop 2013

5a. CONTRACT NUMBER
W911NF-13-1-0375

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
611102

6. AUTHORS
Adilson E. Motter

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
Northwestern University Evanston Campus
1801 Maple Ave.

Evanston, IL 60201 -3149

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
64595-NS-CF.2

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
This grant supported the second edition of the Network Frontier Workshop, a scientific meeting focused on network dynamics held at Northwestern University from December 4 through 6, 2013. The workshop was successful in highlighting leading-edge research on complex networks and in providing opportunities for young researchers and researchers from underrepresented groups.

15. SUBJECT TERMS
Network Science Workshop, Complex Systems, Nonlinear Dynamics

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Adilson Motter
UU	UU	UU	UU		19b. TELEPHONE NUMBER
					847-049-1461

Standard Form 298 (Rev 8/98)
Prescribed by ANSI Std. Z39.18

Report Title

Final Report: Network Frontier Workshop 2013

ABSTRACT

This grant supported the second edition of the Network Frontier Workshop, a scientific meeting focused on network dynamics held at Northwestern University from December 4 through 6, 2013. The workshop was successful in highlighting leading-edge research on complex networks and in providing opportunities for young researchers and researchers from underrepresented groups.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

2013 Fellow of the American Physical Society.

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

The Workshop was attended by 94 participants from 12 different countries, of which 34 were students, 24 were postdoctoral researchers, and 36 were faculty members.

At the meeting, participants working on innovative aspects of complex systems research communicated recent results and ideas relevant to fields as diverse as brain, climate, and socio-technological research. Presentations included both theory and applications of nonlinear dynamics and statistical physics in the context of synchronization, cascades, transportation, control, and failure recovery in complex dynamical systems. The meeting was run in a single session to facilitate interactions between different subfields. The first day of the meeting was dedicated to tutorials and presentations from young researchers. The second and third days were focused mainly on talks from invited speakers. A poster session was held on the second day. Four special talks were also held throughout the meeting: a lunch talk, an evening talk, a poster-session talk, and a colloquium jointly organized with the Department of Physics and Astronomy of Northwestern University. In total, the meeting included 49 talks and 15 poster presentations.

Six of the 18 invited participants were women, leading to a total of 18 female participants. In addition to the non-local invited speakers, 36 contributed participants received partial support to attend the meeting, in the form of waived registration fee, lodging support and/or transportation support. The supported contributed participants included 20 students and 14 postdoctoral researchers. Effort was made to engage the community: the lunch talk mentioned above was open to the Northwestern SIAM Student Chapter members and the colloquium was open to the public. Therefore, diversity and the education of the next generation of network science researchers were at the center of our event.

Technology Transfer

N/A

Network Frontier Workshop 2013
Final Report

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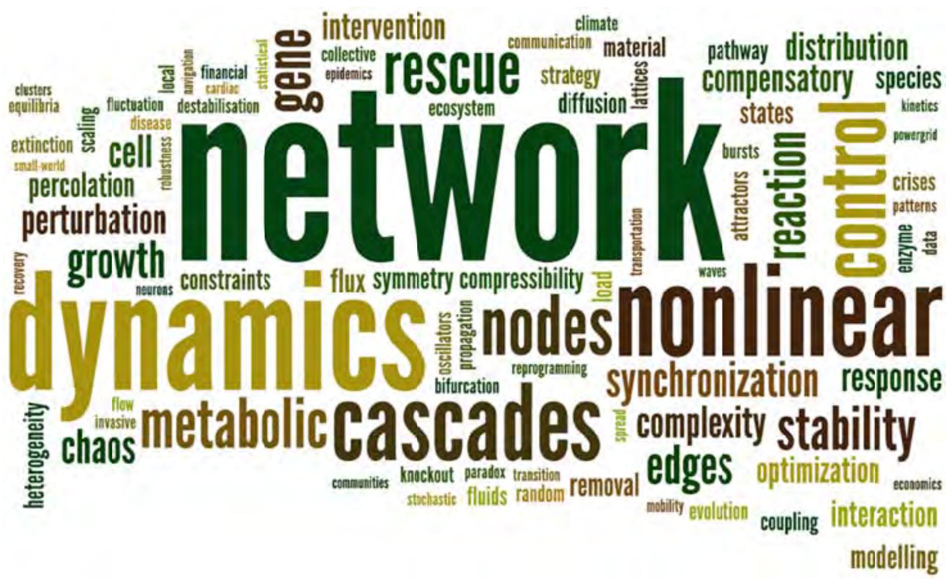
Network Frontier Workshop

Highlighting leading-edge research on complex networks



Program

December 4 – 6, 2013

Northwestern University
Chambers Hall
600 Foster Street
Evanston, IL 60208
USA

Organization:
Adilson E. Motter, Scientific Organizer
Luciana Zanella, Administrative Organizer
Daniel M. Abrams, Advisory Board Member
Takashi Nishikawa, Advisory Board Member

Schedule

Wednesday, December 4

8:30 – 8:55	Registration (Chambers Hall)
8:55 – 9:00	Opening Remarks
9:00 – 9:45	Rosemary Braun (Northwestern University, USA) *Tutorial – Form and Function in the Architecture of Intracellular Networks*
9:45 – 10:00	Bradly Alicea (Michigan State University, USA) *From Switches to Convolution to Tangled Webs: Evolving Sub-Optimal, Subtle Biological Mechanisms*
10:00 – 10:15	Daniel Larremore (Harvard School of Public Health, USA) *Revealing Constraints on Genetic Recombination among Malaria Parasites by Mapping Genetic Sequences to Complex Networks*
10:15 – 10:30	Tin Yau Pang (Stony Brook University, USA) *Universal Distribution of Component Frequencies in Biological and Technological Systems*
10:30 – 11:00	Coffee Break
11:00 – 11:45	Elad Harel (Northwestern University, USA) *Tutorial – Supercontinuum Multi-Dimensional Spectroscopy for the Study of Energy Flow through Molecular Networks*
11:45 – 12:00	Jen Schwarz (Syracuse University, USA) *Jamming Graphs: A Local Approach to Global Mechanical Rigidity*
12:00 – 12:15	Yasmin Khorramzadeh (Virginia Tech, USA) *Analyzing Edge Criticality Using a Reliability-Based Measure*
12:15 – 12:30	Dane Taylor (University of North Carolina, USA) *Dynamics in Hybrid Complex Systems of Switches and Oscillators*
12:30 – 12:45	Mark Panaggio (Northwestern University, USA) *Coupled Oscillators on a Sphere*
12:45 – 2:15	Lunch Break (Allen Center)
1:10 – 1:50	Danielle S. Bassett (University of Pennsylvania, USA) *Probing Human Brain Network Dynamics During Learning*
2:15 – 3:00	Sean Cornelius (Northwestern University, USA) *Tutorial –* Nonlinear Network Dynamics and Cascade Control
3:00 – 3:15	Tom Hurd (McMaster University, Canada) *Illiquidity and Insolvency Cascades in the Interbank Network*
3:15 – 3:30	Thomas Wytock (Northwestern University, USA) *Model-Independent Design of Cell Reprogramming Transitions*
3:30 – 3:45	Takaaki Aoki (Kagawa University, Japan) *Self-Organized Network Structure Emerging from Co-Evolving Dynamics between Resources on Nodes and Weighted Connections*
3:45 – 4:15	Coffee Break

4:15 – 5:00	Bruce J. West (Army Research Office, USA) *Tutorial – Fractional Calculus View of Complexity*
5:00 – 5:15	Jorge G. T. Zañudo (The Pennsylvania State University, USA) *An Effective Network Reduction Approach to Find the Dynamical Repertoire of Discrete Dynamic Models*
5:15 – 5:30	Demetris Antoniades (Georgia Institute of Technology, USA) *Co-Evolutionary Dynamics in Social Networks: A Case Study of Twitter*
5:30 – 5:45	Michael Szell (Massachusetts Institute of Technology, USA) *Taxi Pooling in New York City: A Network-Based Approach to Social Sharing Problems*
5:45 – 6:00	Roberta Sinatra (Northeastern University, USA) *Scientific Success: The Story of Your Big Hit*
6:30 – 8:30	Poster Session and Reception (Technological Institute, Jerome B. Cohen Commons)
6:45 – 7:15	Daniel Abrams (Northwestern University, USA) *Lefties, Languages and (Religious) Leavers: Network Structure and Social Group Competition Dynamics*

Thursday, December 5

8:30 – 8:55	Registration (Chambers Hall)
8:55 – 9:00	Opening Remarks
9:00 – 9:40	Luís A. N. Amaral (Northwestern University, USA) *Network Approaches to Topic Modeling*
9:40 – 10:15	Hawoong Jeong (Korea Advanced Institute of Science and Technology, Korea) *Google Knows (Almost) Everything! – Big-Data and Network Science*
10:15 – 10:30	Maksim Kitsak (Northeastern University, USA) *Popularity versus Similarity in Growing Networks*
10:30 – 11:00	Coffee Break
11:00 – 11:35	Anna Nagurney (University of Massachusetts, Amherst, USA) *Envisioning a Future Internet Architecture: The Network Economics of ChoiceNet*
11:35 – 12:10	Marta C. González (Massachusetts Institute of Technology, USA) *Tackling Urban Challenges with Information and Communications Technologies*
12:10 – 12:25	Sang Hoon Lee (University of Oxford, England) *Density and Transport-Based Core-Periphery Structures in Networks*
12:25 – 12:40	Yong-Yeol Ahn (Indiana University, Bloomington, USA) *Network Communities and Viral Memes*
12:40 – 2:15	Lunch Break (Allen Center)
2:15 – 2:55	Zoltán Toroczkai (University of Notre Dame, USA) *A Distance Rule Based Predictive Model of the Cortical Brain Network*
2:55 – 3:10	Juan G Restrepo (University of Colorado at Boulder, USA) *Self-Sustained Critical Dynamics in Networks of Excitatory and Inhibitory Excitable Systems*
3:10 – 3:25	Epaminondas Rosa (Illinois State University, USA) *Mathematical Model for the Stomatogastric Nervous Systems of the Crab Cancer borealis*
3:25 – 3:40	Shane A Squires (University of Maryland, USA) *Stability of Boolean Networks: The Joint Effect of Topology and Update Rules*
3:40 – 4:10	Coffee Break

4:10 – 4:45	Peter J. Mucha (University of North Carolina, Chapel Hill, USA) *Time-Dependent Generalizations of Hub and Authority Scores*
4:45 – 5:20	Alex Arenas (Rovira i Virgili University, Spain) *Multiplex Networks, Structure and Dynamics*
5:20 – 5:35	Kwang-Il Goh (Korea University, Korea) *Co-Evolution Models of Multiplex Networks*
5:35 – 5:50	Mario Giacobini (University of Torino, Italy) *The Importance of Being Multipartite ... or at Least Bipartite*
6:00 – 8:00	Wine and Cheese
6:30 – 7:15	Christopher M. Danforth (University of Vermont, USA) *Remote Sensing of Emotional States in Real-Time – http://hedonometer.org*

Friday, December 6

8:30 – 9:10	Jürgen Kurths (Potsdam Institute for Climate Impact Research, Germany) *How Basin Stability Complements the Linear-Stability Paradigm*
9:10 – 9:45	Naoki Masuda (The University of Tokyo, Japan) *Laplacian Dynamics Slows Down on Temporal Networks*
9:45 – 10:00	Randy A. Freeman (Northwestern University, USA) *Decentralized Synchronization of Heterogeneous Oscillators on Networks with Arbitrary Topology*
10:00 – 10:15	Aaron M. Hagerstrom (University of Maryland, USA) *Symmetries, Cluster Synchronization, and Isolated Desynchronization in Complex Networks*
10:15 – 10:45	Coffee Break
10:45 – 11:20	Vittoria Colizza (INSERM & Université Pierre et Marie Curie, France, and ISI Foundation, Italy) *Heterogeneities and the Spatial Spread of Infectious Diseases*
11:20 – 11:55	Michelle Girvan (University of Maryland, College Park, USA) *Finding New Order in Biological Functions from the Network Structure of Gene Annotations*
11:55 – 12:10	Kai Morino (The University of Tokyo, Japan) *Failure Recovery in Complex Networks Composed of Active and Inactive Oscillators*
12:10 – 12:25	Jie Sun (Clarkson University, USA) *Controllability Transition and Nonlocality in Network Control*
12:25 – 12:40	Yang Yang (Northwestern University, USA) *Network Observability Transitions*
12:40 – 2:15	Lunch Break (Allen Center)
2:15 – 2:55	Albert-László Barabási (Northeastern University and Harvard Medical School, USA) *Network Science: From Structure to Control*
2:55 – 3:10	Daniel Wells (Northwestern University, USA) *Control of Stochastic Switching in Biological Networks*
3:10 – 3:25	Colin Campbell (The Pennsylvania State University, USA) *Stabilization of Perturbed Boolean Network Attractors through Compensatory Interactions*
3:25 – 3:40	Takashi Nishikawa (Northwestern University, USA) *Realistic Modeling of Synchronization in Power-Grid Networks*
3:40 – 6:00	Joint Event with Physics & Astronomy Colloquium (Technological Institute, L-211)
3:40 – 4:00	Refreshments
4:00 – 5:00	Christopher L. DeMarco (University of Wisconsin, Madison, USA) *Describing Power Grid Cascading Outage Dynamics as Phase Transitions in Nearly Hamiltonian Models*
5:00 – 6:00	Closing and Reception

Poster Titles

Saamer Akhshabi (Georgia Institute of Technology, USA)
Hourglass Structures in Hierarchical Modular Systems

Faryad Darabi Sahneh (Kansas State University, USA)
May the Best Meme Win!: New Exploration of Competitive Epidemic Spreading over Arbitrary Multi-Layer Networks

Juan Fernandez-Gracia (Institute for Cross-Disciplinary Physics and Complex Systems, Spain)
Recurrent Mobility Networks and Imperfect Imitation Shape Voting Behavior

Rosangela Follmann (Northwestern University, USA)
Phase Oscillatory Network and Pattern Recognition

Clara Granell (Universitat Rovira i Virgili, Spain)
On the Dynamical Interplay between Awareness and Epidemic Spreading in Multiplex Networks

Arda Halu (Northeastern University, USA)
Multiplex PageRank

Alexander Holiday (Princeton University, USA)
Coarse-Graining Network Dynamics

Qing Ke (Indiana University, USA)
Modeling Tie Strength in Scientific Collaboration Networks

Pan-Jun Kim (Asia Pacific Center for Theoretical Physics, Korea)
Global Analysis of Human Nutrition and Food: What the Human Body Wants

Joo Sang Lee (Northwestern University, USA)
Community Structure of 3D Genome

Azadeh Nematzadeh (Indiana University, USA)
Optimal Network Clustering for Information Diffusion

Feng Bill Shi (University of Chicago, USA)
Hypergraph Representations of the Social World

Alexander Slawik (Northwestern University, USA)
Self-Sustained Oscillations in Silicon Microdisks

Alejandro Tejedor (St. Anthony Falls Laboratory, USA)
Asymmetry in the Evolution of Competing Processes in Networks

Alan Veliz-Cuba (University of Houston, USA)
On the Solution of the Network Inference Problem

Abstracts – Keynote Presentations

Luís A. N. Amaral

HHMI Early Career Scientist
Professor
Chemical & Biological Engineering and Medicine
Northwestern University, USA

Network Approaches to Topic Modeling (Dec 5, 9:00am)

Much of human knowledge sits in databases of unstructured text. In order to leverage this knowledge, we need algorithms that extract and record metadata information for unstructured text documents. For example, assigning topics to documents will enable intelligent search, statistical characterization, and meaningful classification. Latent Dirichlet Allocation (LDA) is the state-of-the-art in topic classification. Here, we perform a systematic theoretical and numerical analysis which reveals that LDA is neither reproducible nor accurate as a classification instrument. Adapting approaches for community detection in networks, we propose a new algorithm which displays high-reproducibility and high-accuracy. Our algorithm promises to make “big data” text analysis systems more reliable.

Albert-László Barabási

Distinguished University Professor
Center for Complex Network Research at Northeastern University, USA
Department of Medicine, Harvard Medical School, USA

Network Science: From Structure to Control (Dec 6, 2:15pm)

Systems as diverse as the World Wide Web, the Internet or the cell are described by highly interconnected networks with amazingly complex topology. Recent studies indicate that these networks are the result of self-organizing processes governed by simple but generic laws, resulting in architectural features that make them much more similar to each other than one would have expected by chance. I will discuss the order characterizing our interconnected world and its implications to network robustness, and control. Indeed, while control theory offers mathematical tools to steer engineered and natural systems towards a desired state, we lack a framework to control complex self-organized systems. I will discuss a recently developed analytical framework to study the controllability of an arbitrary complex directed network, identifying the set of driver nodes whose time-dependent control can guide the system’s dynamics.

Jürgen Kurths

Prof. Dr. Dr. h.c. mult.
Potsdam Institute for Climate Impact Research, Germany

How Basin Stability Complements the Linear-Stability Paradigm (Dec 6, 8:30am)

The human brain, power grids, arrays of coupled lasers and the Amazon rainforest are all characterized by multistability. The likelihood that these systems will remain in the most desirable of their many stable states depends on their stability against significant perturbations, particularly in a state space populated by undesirable states. Here we claim that the traditional linearization-based approach to stability is too local to adequately assess how stable a state is. Instead, we quantify it in terms of basin stability, a new measure related to the volume of the basin of attraction. Basin stability is non-local, nonlinear and easily applicable, even to high-dimensional systems. It provides a long-sought-after explanation for the surprisingly regular topologies of neural networks and power grids, which have eluded theoretical description based solely on linear stability. We anticipate that basin stability will provide a powerful tool for complex systems studies, including the assessment of multistable climatic tipping elements.

Specifically, we employ a novel component-wise version of basin stability, a nonlinear inspection scheme, to investigate how a grid's degree of stability is influenced by certain patterns in the wiring topology. Various statistics from our ensemble simulations all support one main finding: the widespread and cheapest of all connection schemes, namely dead ends and dead trees, strongly diminish stability. For the Northern European power system we demonstrate that the inverse is also true: "healing" dead ends by addition of transmission lines substantially enhances stability. This indicates a crucial smart-design principle for tomorrow's sustainable power grids: add just a few more lines to avoid dead ends.

Reference: P. Menck, J. Heitzig, N. Marwan, and J. Kurths, Nature Physics 9, 89 (2013).

Zoltán Toroczkai

Professor
Physics and Computer Science & Engineering
University of Notre Dame, USA

A Distance Rule Based Predictive Model of the Cortical Brain Network (Dec 5, 2:15pm)

Recent advances in neuroscience have raised interest in large-scale brain networks. Using a consistent database of cortico-cortical connectivity, generated from hemisphere-wide, retrograde tracing experiments in the macaque, we analyzed interareal connection weights and axonal projection distances to reveal an important organizational principle of brain connectivity. Using appropriate graph theoretical measures, we show that although very dense (66%), the interareal network has strong structural specificity. Connection weights exhibit a heavy-tailed lognormal distribution spanning five orders of magnitude and conform to a distance rule reflecting exponential decay with interareal separation. A single-parameter random graph model based on this rule predicts numerous features of the cortical network: (1) the existence of a network core and the distribution of cliques, (2) global and local binary properties, (3) global and local weight-based communication efficiencies modeled as network conductance, and (4) overall wire-length minimization. These findings underscore the importance of distance and weight-based heterogeneity in cortical architecture and processing.

Abstracts – Invited Talks

Alex Arenas

Professor
Computer Science & Mathematics
Rovira i Virgili University, Spain

Multiplex Networks, Structure and Dynamics (Dec 5, 4:45pm)

Modern theory of complex networks is facing new challenges that arise from the necessity of understanding properly the dynamical evolution of real systems. One of such open problems concerns the topological and dynamical characterization of systems made up by two or more interconnected networks. The standard approach in network modeling assumes that every edge (link) is of the same type and consequently considered at the same temporal and topological scale. This is clearly an abstraction of any real topological structure and represents either instantaneous or aggregated interactions over a certain time window. Therefore, to understand the intricate variability of real complex systems, where many different time scales and structural patterns coexist, we need a new scenario, a new level of description. We present the time scales associated to diffusion processes that take place on multiplex networks, i.e., on a set of networks linked through interconnected layers. To this end, we propose the construction of a supra-Laplacian matrix, which consists of a dimensional lifting of the Laplacian matrix of each layer of the multiplex network. We use perturbative analysis to reveal analytically the structure of eigenvectors and eigenvalues of the complete network in terms of the spectral properties of the individual layers. The spectrum of the supra-Laplacian allows us to understand the physics of diffusion-like processes on top of multiplex networks.

Although adjacency matrices are useful to describe traditional single-layer networks, such a representation is sometimes insufficient for the analysis and description of multiplex and time-dependent networks. Such evidence of the importance of multi-level relationships pushed the study of a unified mathematical formulation of multiplexes. We define a unified and self-consistent language, based on a tensorial formulation, which allows us to extend the well-known algebra of "mono-plexes" (i.e., single-layer networks) to the realm of interconnected multi-layer networks.

Danielle S. Bassett

Skirkanich Assistant Professor of Innovation
Bioengineering
University of Pennsylvania, USA

Probing Human Brain Network Dynamics During Learning (Dec 4, 1:10pm)

Human learning is a complex phenomenon requiring network-wide flexibility to adapt existing brain function and precision in selecting new neurophysiological activities to drive desired behavior. Using functional connectivity measurements of brain activity acquired from initial training through mastery of a simple motor skill, we investigate the properties of brain network dynamics that predict individual differences in learning. Functional interactions between brain regions co-evolve with one another during learning in distributed patterns that decrease in size with practice, indicating the emergence of an autonomous subgraph whose dynamics no longer depends on other parts of the network. This consolidation of network dynamics is mirrored in higher-level summary statistics describing the modular organization of the brain, a property that plays a critical role in the selective adaptability present during evolution, development, and optimal network function. Our results indicate that more flexibility during early practice sessions, which we measure by the allegiance of nodes to modules, predicts more extensive learning in later practice sessions. Flexibility is greatest in a periphery of high-level processing regions whose connectivity changes frequently, and is least in a relatively stiff core of output regions whose connectivity changes little in time. The temporal core-periphery structure of human brain dynamics provides a fundamental new approach for understanding how separable functional modules are linked. This, in turn, enables the prediction of fundamental capacities, including the production of complex goal-directed behavior, in humans.

Vittoria Colizza

Senior Research Scientist
INSERM & Université Pierre et Marie Curie (Paris, France)
ISI Foundation (Turin, Italy)

Heterogeneities and the Spatial Spread of Infectious Diseases (Dec 6, 10:45am)

The spatial spread of infectious diseases depends on the interplay between local interactions among hosts (and possibly with vectors), along which transmission can occur, and dissemination opportunities presented by the movements of hosts (and vectors) among different communities or locations in space. Many degrees of heterogeneity may characterize this process, induced by large fluctuations in hosts' features (e.g., mixing behavior, frequency and duration of movements, topology and magnitude of movement fluxes) or by variations in pathogen's specific features (e.g., multiple circulation of different viruses, multiple types of transmission). To address these aspects, I'll present a general theoretical modeling framework taking into account the various heterogeneities at play and explore how these may affect the pandemic potential of an emerging infectious disease. Results are discussed in the realm of specific case studies.

Christopher M. Danforth

Associate Professor
Mathematics & Statistics
University of Vermont, USA

Remote Sensing of Emotional States in Real-Time – http://hedonometer.org (Dec 5, 6:30pm)

Using human evaluation of the happiness of words, we analyze a diverse set of large-scale texts which reflect cultural experience including 50 years of music lyrics, 10 million weblogs, and 50 billion status updates from Twitter. We find that happiness rises and falls with age and distance from the Earth's equator; that the 2008 Presidential Election was the happiest day in the blogosphere in the last 5 years; and that a diverse collection of languages exhibit a pro-social bias. This talk will describe these results in the context of our Computational Story Lab's ongoing efforts to understand the geographical and topological dynamics of large-scale sociotechnical phenomena.

Christopher L. DeMarco

Grainger Professor of Power Engineering
University of Wisconsin, Madison, USA

Describing Power Grid Cascading Outage Dynamics as Phase Transitions in Nearly Hamiltonian Models
(Dec 6, 4:00pm)

The last decade has seen extensive effort devoted to analysis of power grid cascading failure, in which initial outage of a small number of network elements subsequently overloads other components, forcing their removal from service, in turn overloading additional components, potentially expanding to a large large-scale blackout. These methods have been largely restricted to steady state models, while experience in outage events indicates that transient power swings often dominate the final stages of cascading failure, suggesting the need to represent dynamics. Work here develops a dynamic model for cascading grid failure, augmenting "swing dynamics" with specially structured, smoothed representations of protective relays that disconnect transmission lines, generators, and loads. This construction offers a nearly Hamiltonian structure, with the gradient of a scalar "potential-like" function playing a key role. Any partially degraded network configuration yields an equilibrium point, locally stable if that configuration is operable. Cascading failure is then a sequence of transitions between these degraded network equilibria, with vulnerability to transition characterized by the potential barrier to be overcome along a transition path. Exploiting analogous problems in computational chemistry, this talk will describe adaptation of Nudged Elastic Band and String methods to transition path calculation in the power context.

Michelle Girvan

Associate Professor
Physics and Institute for Physical Science and Technology
University of Maryland, College Park, USA

Finding New Order in Biological Functions from the Network Structure of Gene Annotations
(Dec 6, 11:20am)

The Gene Ontology (GO) provides a controlled vocabulary of terms for describing gene functions and specifies how these functional terms are related to each other. Biologists can then submit annotations connecting genes to the appropriate functional terms. We propose a method for using the network structure of gene-term annotations associated with GO to establish an alternate natural grouping of biological functions which is very different from the conceptual hierarchical structure that relates functional terms in the ontology. Unlike the GO hierarchy, which is specifically species neutral, our method captures variation in functional organization across species. As a result, it can provide insights into the evolution of function. Further, grouping terms by our alternate scheme provides a new framework with which to describe and predict the functions of experimentally identified groups of genes. To demonstrate this, we examine a set of gene signatures for cancer and find enrichment with respect to the groups of terms identified through our alternate approach on par with enrichment with respect to branches of the GO hierarchy.

Marta C. González

Gilbert Winslow Career Development Assistant Professor
Civil & Environmental Engineering
Engineering Systems Division
Operations Research Center
Massachusetts Institute of Technology, USA

Tackling Urban Challenges with Information and Communications Technologies (Dec 5, 11:35am)

Time scales differentiate human mobility. While the mechanism for longtime scales has been studied, the underlying mechanism on the daily scale is still unrevealed. Here, we uncover the mechanism responsible for the daily mobility patterns by analyzing the temporal and spatial trajectories of thousands of persons as individual networks. Using the concept of motifs from network theory, we find that only 17 unique networks are present in daily mobility and they follow simple rules. These networks, called here motifs, are sufficient to capture up to 90 per cent of the population in surveys and mobile phone datasets for different countries. Each individual exhibits a characteristic motif, which seems to be stable over several months. Consequently, an analytically tractable framework for Markov chains can reproduce daily human mobility by modeling periods of high-frequency trips followed by periods of lower activity as the key ingredient. We show how this processed information from the data can be brought back to the urban system; as a case of study we focus on strategies to reduce congestion based on targeting most congested roads and the census tracks that are more exposed to the congestion.

Hawoong Jeong

KAIST Chair Professor
Physics
Korea Advanced Institute of Science and Technology, Korea

Google Knows (Almost) Everything! – Big-Data and Network Science (Dec 5, 9:40am)

Network science is an interdisciplinary academic field which studies complex networks such as engineered networks, information networks, biological networks, cognitive and semantic networks and social networks. This field has received a major boost caused by the availability of huge network data resources on the Internet. The field draws on theories and methods including graph theory from mathematics, statistical mechanics from physics, data mining and information visualization from computer science, inferential modeling from statistics, and social structure from sociology to understand complex systems, which is the problem to be solved in the 21st century. Another research field gaining huge attention nowadays is big-data. Big-data is defined as "high-volume, high-velocity, and/or high-variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization" by Gartner, Inc. This field of research has huge potential for practical applications but it also promises new discoveries in science. However, these big-data should be combined and analyzed together to be useful, and in this respect, network science will shed a light on analyzing these big-data in a more combined way. In this presentation, I will briefly review what we can do by combining big-data, especially using Google and network science together to study various complex systems such as social networks, prediction of science and technology trends, etc.

Naoki Masuda

Associate Professor
Mathematical Informatics
The University of Tokyo, Japan

Laplacian Dynamics Slows Down on Temporal Networks (Dec 6, 9:10am)

Interactions among units in networks often occur in a specific sequential order to affect dynamical processes on networks. Networks composed of time-dependent contacts between nodes are collectively called temporal networks, which are an intensively studied topic nowadays. We theoretically examine the Laplacian spectrum of temporal networks to be compared with that of the corresponding aggregate networks. We show that the Laplacian eigenvalues are smaller (i.e., closer to zero) for temporal than aggregate networks for different scenarios of temporal network realizations derived from the same aggregate network. Therefore, diffusive dynamics is slower in temporal than in aggregate networks. This work has been done in collaboration with Konstantin Klemm and Víctor M. Eguíluz.

Peter J. Mucha

Bowman and Gordon Gray Distinguished Term Professor
Mathematics and Applied Physical Sciences
University of North Carolina, Chapel Hill, USA

Time-Dependent Generalizations of Hub and Authority Scores (Dec 5, 4:10pm)

We calculate centralities in directed temporal networks by constructing a generalization of hub and authority scores for "multilayer" networks that tracks relations between nodes through time. By varying the amount of coupling between layers, we develop a family of centrality measures whose values are localized in time in one extreme and constant across time in the other. The strongly-coupled singular limit can be numerically stabilized via a singular value decomposition and analytically identified using a perturbative expansion. Using examples from the academic genealogy of mathematicians, actors in movies, and co-citations of U.S. Supreme Court decisions, we compare the multilayer hub and authority scores to calculations based on time-averaged data. This work is in collaboration with Sean Myers, Elizabeth Leicht, Aaron Clauset and Mason Porter.

Anna Nagurney

John F. Smith Memorial Professor
Operations and Information Management
University of Massachusetts, Amherst, USA

Envisioning a Future Internet Architecture: The Network Economics of ChoiceNet (Dec 5, 11:00am)

The Internet is the critical infrastructure for businesses, the government, the military, and personal communications and has transformed the manner in which we conduct many of our daily economic, financial, and social activities. Several recent trends in technology and network use have pushed the capabilities required of the Internet beyond what can be provided by the currently deployed infrastructure. To address these limitations, the network community has developed a variety of technologies to adapt the functionality of network protocols and services. A critical question that remains unanswered is how to integrate these technologies into an ecosystem, supported by an Economy Plane, that involves users, service providers, and developers in such a way that new ideas can be deployed and used in practice and that innovations can be supported.

In this talk, I will first discuss our recent multi-disciplinary, multi-institutional research, funded by the National Science Foundation (NSF), on an enhanced Internet, known as ChoiceNet. Our ChoiceNet system is based on three tightly coupled principles in that it aims to (1) encourage alternatives to allow users to choose among a range of services, (2) let users vote with their wallets to reward superior and innovative services, and (3) provide the mechanisms to stay informed on available alternatives and their performance. This approach ensures that innovative technical solutions can be deployed and rewarded through a comprehensive system where solutions can be incorporated and compete to allow the network to adapt to current and future challenges. I will then describe a game theory model, based on network economics, that captures the complexity and the dynamics of the various interacting actors/agents.

Abstracts – Tutorial Talks

Rosemary Braun

Assistant Professor
Preventive Medicine
Northwestern University, USA

Form and Function in the Architecture of Intracellular Networks (Dec 4, 9:00am)

The regulation of cellular processes such as differentiation and cell-cycle progression is governed by networks of interacting molecules that produce complex dynamics and which modulate them in response to external stimuli. These systems are finely tuned to produce precise biological effects, yet flexible enough to adapt to environmental changes and robust enough to tolerate extrinsic and intrinsic variability. Because aberrations in these mechanisms give rise to a multitude of diseases (most notably cancers), a precise understanding of the form and function of intracellular networks is the central goal of modern systems biology research.

Today, high-throughput genomic sequence, expression, and epigenetic profiling assays enable researchers to probe these systems in exquisitely fine experimental detail by simultaneously measuring millions of markers per sample. While the high dimensionality of this data presents novel analytical challenges, it also provides an unprecedented opportunity to deduce the networks of interactions involved in signal transduction and transcriptional regulation. In addition, the combination of high-throughput experimental data with existing network models allows us to analyze genomic data at the systems level and apply graph-theoretic techniques to discern variations that lead to functional differences in the activity of these networks.

In this talk, I will describe the major computational methods developed for the systems-level analysis and reconstruction of intracellular networks, review the biological insights that have been obtained from graph-theoretic approaches, and discuss the extension of static network analyses into dynamic models capable of yielding a new layer of insight into the function of cellular systems.

Elad Harel

Assistant Professor
Chemistry
Northwestern University, USA

Supercontinuum Multi-Dimensional Spectroscopy for the Study of Energy Flow through Molecular Networks (Dec 4, 11:00am)

Electronic structure and dynamics determine material properties and behavior. Two-dimensional (2D) optical spectroscopy has proven an incisive tool to probe fast spatiotemporal electronic dynamics in complex molecular networks. In this tutorial, we discuss the development of single-shot coherent spectroscopy coupled to super-continuum generation to capture 2D ultrabroadband spectra in a single laser pulse. This tool may be used to investigate fundamental energy transfer dynamics in complex systems with multiple absorbers or as a general tool for characterization and identification of coupled molecular systems by optical spectroscopy.

Sean Cornelius

Graduate Student
Physics & Astronomy
Northwestern University, USA

Nonlinear Network Dynamics and Cascade Control (Dec 4, 2:15pm)

Network science has the potential to make far-reaching contributions in areas as diverse as drug targeting, ecosystem management, and infrastructure design. But rarely is the fundamental question asked: what are the common properties that unite these diverse areas? Put another way, what is a "network"? A naïve definition along the lines of "any collection of interconnected objects" is inadequate, as it fails to capture the *dynamical* behaviors networked systems can present, such as synchronization, self-organization, and cascading failures. In this tutorial, I will explore some of the signatures of network dynamics, drawing examples from across the biological and physical sciences. I thereby hope to uncover the essential elements that make a network a "network" from a dynamical perspective. Through their interplay with structure, these properties—including multistability and nonlinearity—introduce unique challenges to network systems, particularly the vulnerability to cascading failures. But I will show how the same properties also create unprecedented opportunities for networks' rescue, reprogramming, and control.

Bruce J. West

Chief Scientist
Mathematics and Information Sciences Directorate
Army Research Office, USA

Fractional Calculus View of Complexity: A Tutorial
(Dec 4, 4:15pm)

The fractional calculus has been part of the mathematics/ science literature for 310 years. However it is only in the past decade or so that it has drawn the attention of mainstream science as a way to describe the dynamics of complex phenomena with long-term memory, spatial heterogeneity, along with non-stationary and non-ergodic statistics. The most recent application encompasses complex networks, which require new ways of thinking about the world. Part of the new cognition is provided by the fractional calculus description of temporal and topological complexity. Consequently, this presentation is not so much a tutorial on the mathematics of the fractional calculus as it is an exploration of how complex physical and social phenomena that have eluded traditional mathematical modeling become less mysterious when certain historical assumptions such as differentiability are discarded and the ordinary calculus is replaced with the fractional calculus. Exemplars considered include the fractional differential equations describing the dynamics of viscoelastic materials, turbulence and phase transitions in complex social networks.

Abstracts – Contributed Talks

Daniel Abrams
Northwestern University, USA

Lefties, Languages and (Religious) Leavers: Network Structure and Social Group Competition Dynamics
(Dec 4, 6:45pm)

This talk will be a light overview of three applications for social group competition models: the evolution of left-handedness, the death of languages, and the growth of religiously unaffiliated populations. Models with global coupling are solvable and interesting, but more realistic social interaction networks give surprising results.

Yong-Yeol Ahn
Indiana University, Bloomington, USA

Network Communities and Viral Memes
(Dec 5, 12:25pm)

How does network structure affect diffusion? Recent studies suggest that the answer depends on the type of contagion. Complex contagions, unlike infectious diseases (simple contagions), are affected by social reinforcement and homophily. Hence, the spread within highly clustered communities is enhanced, while diffusion across communities is hampered. A common hypothesis is that

memes and behaviors are complex contagions. We show that, while most memes indeed spread like complex contagions, a few viral memes spread across many communities, like diseases. We demonstrate that the future popularity of a meme can be predicted by quantifying its early spreading pattern in terms of community concentration. The more communities a meme permeates, the more viral it is. We present a practical method to translate data about community structure into predictive knowledge about what information will spread widely. This connection contributes to our understanding in computational social science, social media analytics, and marketing applications.
Co-authors: L. Weng and F.Menczer

Bradly J. Alicea
Michigan State University, USA

From Switches to Convolution to Tangled Webs: Evolving Sub-Optimal, Subtle Biological Mechanisms (Dec 4, 9:45am)

One way to understand complexity in biological networks is to isolate simple motifs like switches and bi-fans. However, this does not fully capture the outcomes of evolutionary processes. In this talk, I will introduce a class of process model called convolution architectures. These models demonstrate bricolage and ad-hoc formation of new mechanisms atop existing complexity. Unlike simple motifs (e.g., straightforward mechanisms), these models are intended to demonstrate how evolution can produce complex processes that operate in a sub-optimal fashion.

The concept of convolution architectures (Alicea, arXiv: 1104.3559, 2011) can be extended to complex network topologies. Simple convolution architectures with evolutionary constraints and subject to natural selection can produce step lengths that deviate from optimal expectation. When convolution architectures are represented as components of bidirectional complex network topologies, these circuitous paths should become “spaghetti-fied”, as they are not explicitly constrained by inputs and outputs. This may also allow for itinerant and cyclic self-regulation resembling chaotic dynamics.

The use of complex network topologies also allows us to better understand how higher-level constraints (e.g., hub formation, modularity, preferential attachment) affect the evolution of sub-optimality and subtlety. Such embedded convolution architectures are also useful for modeling physiological, economic, and social complexity.

Demetris Antoniades
Georgia Institute of Technology, USA

Co-Evolutionary Dynamics in Social Networks: A Case Study of Twitter (Dec 4, 5:15pm)

Dynamics on networks refer to changes in the state of network nodes or links considering a static topology. Dynamics of networks refer to changes in the topology of a network, without explicitly modeling its underlying causes. Real networks often exhibit both types of dynamics, forming an adaptive, or co-evolutionary, system in which the network topology and the state of nodes/links affect each other in a feedback loop. We focus on the co-evolutionary dynamics of online social networks, and on Twitter in particular. We show the presence of such co-evolutionary dynamics, propose a model to capture the probability and timing of their occurrence, and discuss their importance in terms of network structure and function. We mostly focus on one form of co-evolutionary dynamics in Twitter, namely the addition of new follower links as a result of retweets. Monitoring the activity of thousands of Twitter users in almost real-time, and tracking their followers and tweets/retweets, we collect data that allow the inference of such new retweet-driven follower relations. We show that the formation of such relations is much more likely than the exogenous arrival of new followers in the absence of any retweets, and identify the most significant factors in this effect, namely, reciprocity and the number of retweets that a potential new follower receives in a given time interval. We also discuss the implications of such co-evolutionary dynamics on the topology and function of an online social network. Finally, we briefly consider a second instance of co-evolutionary dynamics on Twitter, namely the possibility that a user removes a follower link after receiving a tweet or retweet from the corresponding followee.
Co-author: C. Dovrolis

Takaaki Aoki
Kagawa University, Japan

Self-Organized Network Structure Emerging from Co-Evolving Dynamics between Resources on Nodes and Weighted Connections (Dec 4, 3:30pm)

Real-world networks continuously change with time, in which the reformation of the networks and the dynamical processes occurring on the networks are interdependent. To understand the mechanisms governing such dynamical network organization, we present a simple model of co-

evolving network dynamics considering the interplay between them, combining the dynamics of random walkers and the dynamics of the weighted network. We consider a single quantity at each node as the “resource”, which may be, for example, molecules, cells, people, money, or data packets, and introduce a diffusion dynamics of the resource on a weighted network. Simultaneously, the interactions between the nodes change with time as a function of the resource. Then, we study how the resource distributes on the network at the equilibrium state, and at the same time, what type of structure of the weighted network is organized. We then find that, under suitable conditions, the quantities of the resources and the link weights converge to stationary power-law distributions at the macroscopic level, but they continue to change with time at the microscopic level, even though the dynamics of the proposed model is deterministic without any random processes.
Co-author: T. Aoyagi

Colin Campbell
The Pennsylvania State University, USA

Stabilization of Perturbed Boolean Network Attractors through Compensatory Interactions (Dec 6, 3:10pm)

Boolean models can effectively model the behavior of biological regulatory and signaling networks. In such a model, system components are characterized by time-varying binary activation levels (e.g., *ON* or *OFF*), which are regulated by logical functions based on component interactions (e.g., *A* = B AND NOT C*). Network attractors (i.e., stable dynamic configurations) may, depending on the system being modeled, represent the response to a signal, differing cell types, or oscillations such as circadian rhythms. Perturbations such as genetic mutations alter the behavior of the system; for example, cells may be perturbed from a healthy phenotype to a cancerous phenotype. Understanding and ameliorating the effects of network damage are therefore of considerable interest. In this talk, I will discuss a methodological framework for modifying logical interaction rules in damaged Boolean networks in such a way as to preserve network attractors (i.e., prevent the network damage from triggering a deregulatory cascade). I will show that the approach is applicable to both synchronously and asynchronously updated networks, for both steady state (fixed point) and limit cycle (fluctuating) attractors. I will discuss applications of the approach to case studies from cancer and plant biology.
Co-author: R. Albert

Randy A. Freeman
Northwestern University, USA

Decentralized Synchronization of Heterogeneous Oscillators on Networks with Arbitrary Topology
(Dec 6, 9:45am)

Oscillator synchronization is an instrumental component of many engineering applications. For example, it can provide networked devices with a common temporal reference necessary for coordinating actions or decoding transmitted messages. In this talk, we study the problem of achieving both phase and frequency synchronization on a network of heterogeneous oscillators using only local measurements. Most current solutions suffer from phase differences in steady state due to frequency heterogeneity; others provide a convergence analysis which is valid only locally, only under synchronous adaptation, or only under a regular graph structure. In contrast, our solutions can exhibit little or no steady state phase differences under arbitrary frequency heterogeneity. Furthermore, we provide a global convergence analysis valid on arbitrary connected graphs and either in continuous time or under sufficiently fast asynchronous updates.
Co-authors: E. Mallada and A. Tang

Jorge G. T. Zañudo
The Pennsylvania State University, USA

An Effective Network Reduction Approach to Find the Dynamical Repertoire of Discrete Dynamic Models
(Dec 4, 5:00pm)

Despite all the progress in developing analysis tools for discrete dynamic models, there is still a need to find approaches that can directly relate the network structure to its attractors (stable patterns of activity). Here we present a novel network reduction approach that can be efficiently applied to large network sizes (up to size 1000) and has been shown to find all the attractors of the system. This method is based on a topological criterion to find network motifs that stabilize in a fixed state. Combining these network motifs with network reduction techniques, our method predicts the dynamical repertoire of the nodes (fixed states or oscillations) in the system’s attractors. Furthermore, by applying our method to several biological network models, we have found that these network motifs play a significant role in the biology of the modeled system, and also provide insights into how to control the dynamics of the network.

We are currently exploring the relationship between these network motifs and network control.
Co-author: R. Albert

Mario Giacobini
University of Torino, Italy

The Importance of Being Multipartite ... or at Least Bipartite (Dec 5, 5:35pm)

Many real world phenomena are naturally represented by multipartite networks. However, most of the time, researchers tend to prefer to work on their projections over a single class of nodes. Since it can be easily proven that projecting the network implies a loss of (sometimes key) information, we believe that one should carefully justify such a choice. In this talk, examples of the use of multipartite networks for real phenomena will be given, ranging from social systems (the We-Sport social network) to musical phenomena (the history of the MiTo-Settembre Musica musical festival). Particular attention will be then given to modeling epidemiological dynamics over these structures, as in the case of tick-borne pathogens' transmission cycle.

Kwang-Il Goh
Korea University, Korea

Co-Evolution Models of Multiplex Networks
(Dec 5, 5:20pm)

Distinct channels of interaction in a complex networked system define network layers, which coexist and cooperate for the system's function. Towards understanding such multiplex systems, we propose a modeling framework based on co-evolution of network layers, with a class of minimalistic growing network models as working examples. We examine how the entangled growth of co-evolving layers can shape the network structure and show analytically and numerically that the co-evolution can induce strong degree correlations across layers, as well as modulate degree distributions. We further show that such a co-evolution-induced correlated multiplexity can alter the system's response to the dynamical process, exemplified by the suppressed susceptibility to a social cascade process.
Co-authors: J.Y. Kim and J.-H. Kim

Aaron M. Hagerstrom
University of Maryland, USA

Symmetries, Cluster Synchronization, and Isolated Desynchronization in Complex Networks
(Dec 6, 10:00am)

Synchronization is of central importance in power distribution, telecommunication, neuronal, and biological networks. Many networks are observed to produce patterns of synchronized clusters, but it has been difficult to predict these clusters or understand the conditions under which they form, except for in the simplest of networks. In this article, we shed light on the intimate connection between network symmetry and cluster synchronization. We introduce general techniques that use network symmetries to reveal the patterns of synchronized clusters and determine the conditions under which they persist. The connection between symmetry and cluster synchronization is experimentally explored using an electro-optic network. We experimentally observe and theoretically predict a surprising phenomenon in which some clusters lose synchrony while leaving others synchronized. The results could guide the design of new power grid systems or lead to new understanding of the dynamical behavior of networks ranging from neural to social.
Co-authors: L.M. Pecora, F. Sorrentino, T.E. Murphy, and R. Roy

Tom Hurd
McMaster University, Canada

Illiquidity and Insolvency Cascades in the Interbank Network (Dec 4, 3:00pm)

The great crisis of 2007-08, followed by the ongoing Euro crisis, has highlighted the need for better mathematical and economic understanding of financial systemic risk. Are there "toy models" of systemic risk that are amenable to an exact probabilistic analysis? How do these models work, how useful are they, and what are some of the conclusions that can be drawn from them?

Yasmin Khorramzadeh
Virginia Tech, USA

Analyzing Edge Criticality Using a Reliability-Based Measure (Dec 4, 12:00pm)

We demonstrate how to compare networks using a novel family of measures of an edge's contribution to particular

aspects of diffusion dynamics on a network. These centrality measures are based on membership in structural motifs that determine the network's reliability, as introduced by Moore and Shannon in 1956. The measures are analogous to betweenness, but are more directly related to specific dynamical phenomena. They can be estimated efficiently in a distributed, scalable way with readily controlled precision. We illustrate how these measures can be used to understand which differences between two networks over the same set of vertices are most important, and exactly how those differences affect the dynamics. We focus here on phenomena of interest in network epidemiology, but the methods can easily be generalized to other diffusive processes on a network.
Co-authors: S. Eubank and M. Youssef

Maksim Kitsak
Northeastern University, USA

Popularity versus Similarity in Growing Networks (Dec 5, 10:15am)

The principle that "popularity is attractive" underlies preferential attachment, which is a common explanation for the emergence of scaling in growing networks. If new connections are made preferentially to more popular nodes, then the resulting distribution of the number of connections possessed by nodes follows power laws, as observed in many real networks. Preferential attachment has been directly validated for some real networks (including the Internet), and can be a consequence of different underlying processes based on node fitness, ranking, optimization, random walks or duplication. Here we show that popularity is just one dimension of attractiveness; another dimension is similarity. We develop a framework in which new connections optimize certain trade-offs between popularity and similarity, instead of simply preferring popular nodes. The framework has a geometric interpretation in which popularity preference emerges from local optimization. As opposed to preferential attachment, our optimization framework accurately describes the large-scale evolution of technological (the Internet), social (trust relationships between people) and biological (*Escherichia coli* metabolic) networks, predicting the probability of new links with high precision. The framework that we have developed can thus be used for predicting new links in evolving networks, and provides a different perspective on preferential attachment as an emergent phenomenon.

Daniel B Larremore
Harvard School of Public Health, USA

Revealing Constraints on Genetic Recombination among Malaria Parasites by Mapping Genetic Sequences to Complex Networks (Dec 4, 10:00am)

Malaria parasites evade the human immune system by sequentially expressing diverse proteins on the surface of infected red blood cells. The diversity of these camouflage proteins comes from rapid genetic recombination that shuffles the genes that encode the proteins. Unfortunately, this shuffling precludes the use of traditional sequence analysis techniques, such as multiple alignments, and phylogenetic trees. We therefore take a new approach by mapping sequences to a complex network in which each vertex represents a single sequence and constraints on recombination reveal themselves in the community structure of the network. We validate this map and the networks it produces on synthetic sequences, before applying it to multiple different locations in the malaria immune evasion genes. We find that different pieces of the immune evasion proteins are under different types of evolutionary selection, with implications for theoreticians and clinicians alike.
Co-authors: A. Clauset and C. Buckee

Sang Hoon Lee
University of Oxford, England

Density and Transport-Based Core-Periphery Structures in Networks (Dec 5, 12:10pm)

Networks often possess mesoscale structures that can be insightful not only structurally but also functionally. It is most common to study community structure but numerous other types of mesoscale structures also exist. In this talk, we examine core-periphery structures based on both density and transportation in several networks. Core network components are well-connected both among themselves and to peripheral components, which are not well-connected to anything. We illustrate that a recently developed transport-based notion of node coreness is useful for characterizing transportation networks. We generalize this notion so that we can also examine core versus peripheral edges, and show that this new diagnostic is also useful for transportation networks. We examine core-periphery structures in a wide range of examples—including road networks in large urban areas, a rabbit warren, a dolphin social network, a European interbank network, and a migration network between

counties in the United States. To examine the properties of transportation networks further, we develop a new family of generative models of road-like networks. We illustrate the effect of the dimensionality of the embedding space on transportation networks, and demonstrate that the correlations between different measures of coreness can be very different for different types of networks.
Co-authors: M. Cucuringu and M.A. Porter

Kai Morino
The University of Tokyo, Japan

Failure Recovery in Complex Networks Composed of Active and Inactive Oscillators (Dec 6, 11:55am)

We have studied recovery of dynamic behavior in coupled oscillator networks composed of self-oscillatory (active) oscillators and self-damping (inactive) ones[1]. When the proportion of inactive oscillators is beyond a critical value in these networks, the global oscillation vanishes[2-4]. In such a damaged network, the global oscillation can recover by adding active oscillators to the oscillators of the damaged networks. We have revealed that the global oscillation is more effectively recovered by adding these supporting oscillators preferentially to active oscillators than to inactive ones in all-to-all networks[1]. In this presentation, we will report recent results on the recovery of dynamic behavior in complex networks.
Co-authors: G. Tanaka and K. Aihara

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Takashi Nishikawa
Northwestern University, USA

Realistic Modeling of Synchronization in Power-Grid Networks (Dec 6, 3:25pm)

An imperative condition for the functioning of a power-grid network is that its power generators remain synchronized. Disturbances can prompt desynchronization, which is a process that has been involved in large power outages. In this talk, I will present an approach for the realistic modeling of power grids, in which the dynamics of the generators are coupled through a network of effective interactions. This approach allows us to derive a condition under which the desired synchronous state is stable, and to use this condition to identify tunable parameters of the generators that are determinants of spontaneous synchronization. This analysis gives rise to a methodology to specify parameter assignments that can enhance synchronization of any given network, which I will demonstrate for a selection of both test systems and real power grids.

Mark Panaggio
Northwestern University, USA

Coupled Oscillators on a Sphere (Dec 4, 12:30pm)

When many identical oscillators interact, surprisingly complex dynamics can result. With global coupling, these oscillators evolve toward coherence or incoherence. However, for near-global coupling schemes, spatiotemporal patterns consisting of coexisting domains of asynchronous and synchronous oscillators known as "chimera states" can appear. I will examine a network of oscillators arranged on the surface of a sphere, describe the influence of the coupling length and coupling phase lag on the types of chimera states that appear, and present numerical evidence for the domains of stability.
Co-author: D. Abrams

Tin Yau Pang
Stony Brook University, USA

Universal Distribution of Component Frequencies in Biological and Technological Systems (Dec 4, 10:15am)

Bacterial genomes and large-scale computer software projects share a number of similarities. They both consist of a large number of components (genes or software packages) connected via a network of mutual dependencies. Components are easily added or removed from individual systems and their occurrence frequencies vary over many orders of magnitude. We studied the frequency of occurrence of genes in genomes of ~500 bacterial species and installation of software packages on over 2 million Linux computers. We found that in both cases, frequency distributions have U-shaped functional form with a power-law scaling for small frequencies and an additional peak at the tail of the distribution corresponding to nearly universal components. A simple mathematically tractable model explaining the frequency distribution and the topology of the mutual dependency network of components is discussed.

Juan G Restrepo
University of Colorado at Boulder, USA

Self-Sustained Critical Dynamics in Networks of Excitatory and Inhibitory Excitable Systems (Dec 5, 2:55pm)

Experimental signatures of critical dynamics in functional brain networks have been successfully modeled using networks of simple excitable systems. However, these models do not typically include inhibitory nodes and cannot sustain critical dynamics without external stimulation. We introduce a model with inhibitory nodes and find that it can sustain critical dynamics with a lifetime that grows exponentially with (Na/k), where N is the number of nodes, a is the fraction of inhibitory nodes, and k is the mean degree of the network. For relevant values of N, a, and k, the critical dynamics are effectively ceaseless. Our analysis is based on the "branching function", which represents the expected fractional growth in the number of active nodes per time step. We find that the branching function calculated from measurements in brain activity of awake monkeys agrees with our predicted branching function. The statistics of avalanches observed in our model also agrees with those obtained experimentally.
Co-authors: D.B. Larremore, W.L. Shew, S. Yu, D. Plenz, E. Ott,and F. Sorrentino

Epaminondas Rosa
Illinois State University, USA

Mathematical Model for the Stomatogastric Nervous Systems of the Crab *Cancer borealis* (Dec 5, 3:10pm)

Even though intensively investigated there remain important open questions regarding rhythmic motor systems driven by Central Pattern Generators (CPGs). One such a question considers that while there is some evidence that continuous entrainment of the motor pattern via sensory feedback supports recovery (for example, after spinal cord injury), it is far from clear what the mechanisms are that drive recovery. In this presentation we introduce a mathematical model for the single neuron first developed for studying neurological thermal sensitivity, and later extended to more general applications. We briefly describe the dynamical properties of the model neuron and show how the model performs in the context of a network driven by a CPG. Simulation results are then compared to experimental data obtained for the stomatogastric nervous systems of the crab *Cancer borealis*.*Co-authors: W. Stein and Q. Skilling*

Jen Schwarz
Syracuse University, USA

Jamming Graphs: A Local Approach to Global Mechanical Rigidity (Dec 4, 11:45am)

We revisit the concept of minimal rigidity as applied to soft repulsive, frictionless sphere packings in two-dimensions with the introduction of the jamming graph. Minimal rigidity is a purely combinatorial property encoded via Laman's theorem in two-dimensions. It constrains the global, average coordination number of the graph, for example. However, minimal rigidity does not address the geometry of local mechanical stability. The jamming graph contains both properties of global mechanical stability at the onset of jamming and local mechanical stability. We demonstrate how jamming graphs can be constructed using local moves via the Henneberg construction such that these graphs fall under the framework of correlated percolation. We then probe how jamming graphs destabilize, or become unjammed, by deleting a bond and computing the resulting rigid cluster distribution. We also study how the system restabilizes with the addition of new contacts and how a jamming graph with extra/redundant contacts destabilizes. The latter endeavor allows us to probe a polydisperse disc packing in the rigid phase and uncover a potentially new diverging lengthscale associated with the random deletion of contacts as compared to the study of cut-out subsystems.
Co-authors: J.H. Lopez and L. Cao

Roberta Sinatra
Northeastern University, USA

Scientific Success: The Story of Your Big Hit (Dec 4, 5:45pm)

A gradual increase in performance through learning and practice characterizes most trades, from sport to music, poetry or engineering, and common sense suggests this to be true in science as well. This prompts us to ask: what are the precise patterns that lead to scientific excellence? Does performance indeed improve throughout a scientific career? Are there quantifiable signs of an impending scientific hit? Using citation based measures as a proxy of impact, we show that (i) major discoveries are not preceded by works of increasing impact, nor are followed by work of higher impact, (ii) the precise time ranking of the highest impact work in a scientist's career is uniformly random, with the higher probability to have a

major discovery in the middle of scientific careers being due only to changes in productivity, (iii) there is a strong correlation between the highest impact work and average impact of a scientist's work. These findings suggest that the impact of a paper is drawn randomly from an impact distribution that is unique for each scientist. We present a model which allows to reconstruct the individual impact distribution, making possible to create synthetic careers that exhibit the same properties of the real data and to define a ranking based on the overall impact of a scientist.
Co-authors: D. Wang, C. Song, P. Deville, and A.-L. Barabási

Shane A. Squires
University of Maryland, USA

Stability of Boolean Networks: The Joint Effect of Topology and Update Rules (Dec 5, 3:25pm)

We study the stability of orbits in large Boolean networks with given complex topology. We impose no restrictions on the form of the update rules, which may be correlated with local topological properties of the network. While recent past work has addressed the separate effects of nontrivial network topology and certain special classes of update rules on stability, only crude results exist about how these effects interact. We present a widely applicable solution to this problem. Numerical experiments confirm our theory and show that local correlations between topology and update rules can have profound effects on the qualitative behavior of these systems.
Co-authors: A. Pomerance, M. Girvan, and E. Ott

Jie Sun
Clarkson University, USA

Controllability Transition and Nonlocality in Network Control (Dec 6, 12:10pm)

A common goal in the control of a large network is to minimize the number of driver nodes or control inputs. Yet, the physical determination of control signals and the properties of the resulting control trajectories remain widely underexplored. In this talk, I will show that (i) numerical control fails in practice even for linear systems if the controllability Gramian is ill conditioned, which occurs frequently even when existing controllability criteria are satisfied unambiguously, (ii) the control trajectories are generally nonlocal in the phase space, and their lengths are strongly anti-correlated with the numerical success rate and number of control inputs, and (iii) numerical success rate increases abruptly from zero to nearly one as the number of control inputs is increased, a transformation we term numerical controllability transition. I will show that this reveals a trade-off between nonlocality of the control trajectory in the phase space and nonlocality of the control inputs in the network itself. The failure of numerical control cannot be overcome in general by merely increasing numerical precision—successful control requires instead increasing the number of control inputs beyond the numerical controllability transition.
Co-author: A.E. Motter

Michael Szell
Massachusetts Institute of Technology, USA

Taxi Pooling in New York City: A Network-Based Approach to Social Sharing Problems (Dec 4, 5:30pm)

Taxi services are a vital part of urban transportation, but the collective performance of a large number of individual vehicles is challenging to assess. Here, using a massive data set of millions of taxi trips taken in New York City, we quantify the potential benefits of a new kind of urban taxi service in which trips are routinely shareable. To minimize the inconveniences that such sharing could entail, our analysis introduces the concept of shareability networks that allows for efficient modeling and optimization of the trip-sharing opportunities. Our network-based algorithm predicts that the cumulative trip length can be cut by 40% when passengers share two trips per taxi, with corresponding reductions in service cost, traffic, and emissions. Simulation of a realistic online dispatch system demonstrates the feasibility of a shareable taxi service in New York City. Shareability as a function of trip density saturates fast, suggesting effectiveness of the sharing system also in cities with much sparser taxi fleets. We anticipate our methodology to be a starting point to the assessment of other ride sharing scenarios and social sharing problems where spatio-temporal conditions for sharing, the incurred discomfort for individual participants, and the collective benefits of sharing, can be formally defined.
Co-authors: P. Santi, G. Resta, S. Sobolevsky, S. Strogatz, and C. Ratti

Dane Taylor
University of North Carolina, USA

Dynamics in Hybrid Complex Systems of Switches and Oscillators (Dec 4, 12:15pm)

While considerable progress has been made in the analysis of large systems containing a single type of coupled dynamical component (e.g., coupled oscillators or coupled switches), systems containing diverse components (e.g., both oscillators and switches) have received much less attention. We analyze large, hybrid systems of interconnected Kuramoto oscillators and Hopfield switches with positive feedback. In this system, oscillator synchronization promotes switches to turn on. In turn, when switches turn on they enhance the synchrony of the oscillators to which they are coupled. Depending on the choice of parameters, we find theoretically coexisting stable solutions with either (i) incoherent oscillators and all switches permanently off, (ii) synchronized oscillators and all switches permanently on, or (iii) synchronized oscillators and switches that periodically alternate between the on and off states. Numerical experiments confirm these predictions. We discuss how transitions between these steady state solutions can be onset deterministically through dynamic bifurcations or spontaneously due to finite-size fluctuations.
Co-authors: J.G. Restrepo and E. Fertig

Daniel Wells
Northwestern University, USA

Control of Stochastic Switching in Biological Networks (Dec 6, 2:55pm)

Noise caused by fluctuations in molecular number is a fundamental part of intracellular processes. While the response of biological systems to noise has been studied extensively, there has been limited understanding of how to control this response and exploit it to induce a desired cell state. Here we present a scalable quantitative method based upon large deviation theory to predict and control rare noise-induced switching between different states in genetic networks. Our analysis can be used to generate a dramatically distilled form of the original network— represented as a "metagenetic" transition network of transition paths, transition rates, and states— whose dynamics can be rationally controlled. Employing this distinct network representation, we consider models of cell differentiation and show how changes in gene activation rates or other tunable factors can lead to desired changes in stochastic switching that induce lineage changes towards pre-specified cell states, promote transdifferentiation, and explain re-specification events. This framework offers a systems approach for rationally manipulating biological dynamics.
Co-authors: W.L. Kath and A.E. Motter

Thomas Wytock
Northwestern University, USA

Model-Independent Design of Cell Reprogramming Transitions (Dec 4, 3:15pm)

Despite decades of careful study of genetic interactions, designing rescue strategies for aberrant genetic networks remains difficult. Because the cell is a dissipative system, we posit that gene expression, as characterized by microarray data, is a property of the underlying dynamical attractor. I will discuss how we design rescue perturbations by looking for transitions between such attractors. To our knowledge, this data-driven analysis is the first to successfully agglomerate thousands of microarray experiments into a model of reprogramming transitions from aberrant to normal gene expression states. The results highlight the mechanistic relationships between cancer attractors and the cooperative role of genetic perturbations in state transitions.
Co-author: A.E. Motter

Yang Yang
Northwestern University, USA

Network Observability Transitions (Dec 6, 12:25pm)

In the modeling, monitoring, and control of complex networks, a fundamental problem concerns the comprehensive determination of the state of the system from limited measurements. Using power grids as example networks, in this talk I will show that this problem leads to a new type of percolation transition, termed network observability transition, which we can solve analytically for the configuration model. I will also demonstrate a dual role of the network's community structure, which both facilitates optimal measurement placement and renders the networks substantially more sensitive to "observability attacks". Aside from their immediate implications for the development of smart grids, these results provide insights into decentralized biological, social, and technological networks.
Co-authors: J. Wang and A.E. Motter

Abstracts – Posters

Saamer Akhshabi
Georgia Institute of Technology, USA

Hourglass Structures in Hierarchical Modular Systems

The architecture of both technological and natural complex systems often exhibits hierarchical modularity: simpler modules are used in the construction of increasingly more complex modules. Such architectures can be modeled as a directed, acyclic, and layered network in which the inputs to the system appear at the bottom layer and the ultimate outcomes of the system are produced at the highest layer. Such networks are often subject to an evolutionary process in which the structure of the network can change over time. An interesting observation in some of these networks is that the evolutionary process leads to an "hourglass" shape: starting from the bottom layer and moving up the hierarchy, the number of modules at each layer decreases until the "waist" of the hourglass, followed by an increase until reaching the top layer. In this talk I will briefly present two models, EvoArch and DevoNet. EvoArch is an abstract model to explain the emergence of the famous Internet protocol stack hourglass. DevoNet is an "evo-devo" model to explain the emergence of the hourglass structure during embryonic development at the genomic level. I will conclude the talk by highlighting the similarities between the two systems.
Co-authors: S. Sarda, C. Dovrolis, and S. Yi

Faryad Darabi Sahneh
Kansas State University, USA

May the Best Meme Win!: New Exploration of Competitive Epidemic Spreading over Arbitrary Multi-Layer Networks

Study of dynamical processes over multilayer networks is emerging as an exciting, yet mathematically challenging research direction in network science. Multilayer networks generate interesting results for competitive viral spreading. Current knowledge of how hybridity of underlying topology influences fate of the spreading viruses is little and limited. In this talk, we study two exclusive, competitive viruses spreading over a two-layer network with generic structure, where network layers represent the distinct transmission routes of the viruses. This model has implications in several applications like product adoption (e.g., Apple vs. Android smart phones), virus-antidode propagation, meme propagation, opposing opinions propagation, and etc. We find analytical results determining extinction, mutual exclusion, and coexistence of the viruses by introducing the concepts of survival threshold and winning threshold. Not only we rigorously prove a region of coexistence, we quantitate it via interrelation of central nodes across the network layers. Little to no overlapping of layers central nodes is the key determinant of coexistence. Specifically, we show coexistence is impossible if network layers are identical yet possible if the network layers have distinct dominant eigenvectors and node degree vectors. Our results shed light on the complex role of multilayer network structure in competitive spreading.
Co-author: C. Scoglio

Juan Fernandez-Gracia
Institute for Cross-Disciplinary Physics and Complex Systems, Spain

Recurrent Mobility Networks and Imperfect Imitation Shape Voting Behavior

The voter model has been studied extensively as a paradigmatic opinion dynamics' model. However, its ability for modeling real opinion dynamics has not been addressed. We introduce a noisy voter model (accounting for social influence) with agents' recurrent mobility (as a proxy for social context), where the spatial and population diversity are taken as inputs to the model. We show that the dynamics can be described as a noisy diffusive process that contains the proper anisotropic coupling topology given by population and mobility heterogeneity. The model captures statistical features of the US presidential elections as the stationary vote-share fluctuations across counties, and the long-range spatial correlations that decay logarithmically with the distance. Furthermore, it recovers the behavior of these properties when a real-space renormalization is performed by coarse-graining the geographical scale from county level through congressional districts and up to states. Finally, we analyze the role of the mobility range and the

randomness in decision making which are consistent with the empirical observations.
Co-authors: K. Suchecki, J.J. Ramasco, M.S.Miguel, and V.M. Eguíluz

Rosangela Follmann
Northwestern University, USA

Phase Oscillatory Network and Pattern Recognition

Preventive detection of epidemics, collective self-organization, information flow and systemic robustness are all examples of problems that can be studied in the context of complex network theory. In particular, self-organization of neuronal network caused by local oscillatory activity, along with the complexity of synaptic connections, plays a key role during cognitive processes. In this presentation, we explore a properly interconnected set of Kuramoto-type oscillators that results in an improved associative-memory network configuration. Investigation of the response of the network to different external stimuli indicates an increase in the network capability for coding and information retrieval. Comparison of the network output with that of an equivalent experiment with subjects, for recognizing perturbed binary patterns, shows comparable results between the two approaches. We also discuss the enhancement of storage capacity of the network.
Co-authors: E.E.N. Macau, E. Rosa, and J.R.C. Piqueira

Clara Granell
Universitat Rovira i Virgili, Spain

On the Dynamical Interplay between Awareness and Epidemic Spreading in Multiplex Networks

We present the analysis of the interrelation between two processes accounting for the spreading of an epidemic, and the information awareness to prevent its infection, on top of multiplex networks. This scenario is representative of an epidemic process spreading on a network of persistent real contacts, and a cyclic information awareness process diffusing in the network of virtual social contacts between the same individuals. The topology corresponds to a multiplex network where two diffusive processes are interacting affecting each other. The analysis using a Microscopic Markov Chain Approach (MMCA) reveals the phase diagram of the incidence of the epidemics and allows capturing the evolution of the epidemic threshold depending on the topological structure of the multiplex and the interrelation with the awareness process. Interestingly, the critical point for the onset of the epidemics has a critical value (meta-critical point) defined by the awareness dynamics and the topology of the virtual network, from which the onset increases and the epidemics incidence decreases.
Co-authors: S. Gómez and A. Arenas

Arda Halu
Northeastern University, USA

Multiplex PageRank

A realistic description of many complex systems can be achieved by considering interacting layers of networks. Multiplex networks are a class of interacting networks where the same set of nodes can interact with each other on different layers via different types of connections. Delineating the centrality and the ensuing ranking of nodes on multiplex networks is a nontrivial task, as the importance of nodes should be affected by the interactions in one layer as well as in the other interdependent layers. In this study, we introduce the Multiplex PageRank centrality measure, inspired by the concept of biased random walks, which directly takes into account the interplay of the different layers when determining the ranking of a node. We define four versions of Multiplex PageRank and present their implementation on a multiplex social network of online communities. We show that considering the multiplex nature of networks results in a ranking that differs from the rankings of single networks. Our findings thus indicate the potential of multiplex centrality measures such as Multiplex PageRank in uncovering the prominence of nodes that would go undetected in the isolated network approach.
Co-authors: R.J. Mondragon, P. Panzarasa, and G. Bianconi

Alexander Holiday
Princeton University, USA

Coarse-Graining Network Dynamics

Simulating large, complex networks is often computationally prohibitive, while the resulting high-dimensional data hides meaningful correlations between variables and dynamics making the selection of good macroscopic observables difficult. Dimensionality reduction algorithms hold the potential to effectively reduce large network dynamics problems, enabling the

detection of a manageable, lower-dimensional set of variables. This reduced description would, in turn, enable a broad range of equation-free, coarse-grained numerical methods such as coarse bifurcation analysis and coarse projective integration. To illustrate this research program of our group, we present two different techniques for extracting low-dimensional descriptions of networks and their dynamics. First, we show that nonlinear manifold learning techniques – in particular, "diffusion maps" – equipped with a good definition of network similarity, are capable of analyzing ensembles of networks and extracting an appropriate reduced system. Second, we demonstrate how ideas from uncertainty quantification can be used to encode both structural and intrinsic heterogeneity for dynamics on networks; this is accomplished by expanding the network state in terms of polynomial chaos basis functions.
Co-authors: T. Bertalan, K. Rajendran, and I. Kevrekidis

Qing Ke
Indiana University, USA

Modeling Tie Strength in Scientific Collaboration Networks

Science is increasingly dominated by teams. Understanding patterns of scientific collaboration and their impacts on the productivity and evolution of disciplines is crucial to understand scientific processes. Electronic bibliography offers a unique opportunity to map and investigate the nature of scientific collaboration. Recent work have demonstrated a counter-intuitive organizational pattern of scientific collaboration networks: densely interconnected local clusters consist of weak ties, whereas strong ties play the role of connecting different clusters. This pattern contrasts itself from many other types of networks where strong ties form communities while weak ties connect different communities. Although there are many models for collaboration networks, no model reproduces this pattern. In this paper, we present an evolution model of collaboration networks, which reproduces many properties of real-world collaboration networks, including the organization of tie strengths, skewed degree and weight distribution, high clustering and assortative mixing.
Co-author: Y.-Y. Ahn

Pan-Jun Kim
Asia Pacific Center for Theoretical Physics, Korea

Global Analysis of Human Nutrition and Food: What the Human Body Wants

Daily diet has significant effect on human health, thus it is important to understand the interplay among food, nutrients, and their dietary intake. However, there are only a few studies available that take a systems approach for analysis of large-scale food datasets. Here, we developed a systematic way to quantify nutritional quality of ~600 food products in the U.S. market and suggest how network organization of food and nutrients facilitates analysis of the results. We showed that the nutritional quality of individual food products is not necessarily compatible with the price of the product and found what bottleneck nutrients mainly contribute to nutritional quality. Whether agonistic or antagonistic in nutritional quality turned out to be elaborately organized with homophily of given nutrient pairs in the nutrient-nutrient network. Our work provides a useful framework applicable for planning of international food aid and personalized nutrition.
Co-authors: S. Kim andY.-S. Jin

Joo Sang Lee
Northwestern University, USA

Community Structure of 3D Genome

Large-scale chromatin structure plays an important role in regulating global gene repression, cell cycle dynamics, and cell proliferation. Despite the advancement of genomics tools to analyze the nuclear genome organization, its role in the course of malignant transformation remains unclear. Here, I will present on the structural alteration of the nuclear architecture and its consequences for the metabolic phenotype of transformed cells. I will discuss how chromosome conformation captured with high-throughput sequencing (Hi-C) data can be analyzed using the modularity analysis previously introduced to identify the community structure of networks. I will show that (i) the distribution of communities is consistent with other structural queues of genomic architecture, (ii) the communities of genes that are associated with metabolic pathways are non-random, and (iii) the deregulation of metabolic pathways is partly explained by the spatial disorganization of genes associated with central metabolic pathways such as glycolysis and the citric acid cycle. This study identifies a new co-localization pattern of genes associated with

metabolic pathways and provides a computational framework to link the genomic structure to its phenotypes.
Co-authors: J.F. Marko and A.E. Motter

Azadeh Nematzadeh
Indiana University, USA

Optimal Network Clustering for Information Diffusion

How can global spreading behavior emerge from local spreading in a clustered network? Assuming that information diffusion is affected by social reinforcement and visibility of the new contagion effect, we demonstrate an optimal network clustering to achieve such global information diffusion and to decrease the size of early innovators. We estimate information diffusion size as a function of the early innovators' fraction and of the number of bridges between two communities. We then demonstrate that certain global network characteristics can cause a newly introduced contagion to spread from a small number of early innovators to the network at large. Additionally, we show that both the highly dense communities and the sparse communities hinder global information diffusion for the small early innovators' fraction. Agent based simulation confirms these analytic results.
Co-authors: E. Ferrara, Y.-Y. Ahn,and A. Flammini

Feng Bill Shi
University of Chicago, USA

Hypergraph Representations of the Social World

Complex networks have attracted increasing attention over the past half century. Many real systems and interactions among "actors" within those systems are well modeled by network structure and a corresponding graph/matrix representation. In many systems, however, including social systems (but also systems of ideas, reacting chemicals, etc.), relationships among actors are typically not dyadic and a higher-order structure is needed to fully describe group interaction. Here we demonstrate the application of hypergraphs as a model for such systems; then we apply the theory to a hypergraph of science (i.e., scientists using biomedical methods to study diseases and chemicals across papers in MEDLINE) to explore the beliefs, practices, and theories that shape and limit pathways of scientific innovation.
Co-authors: J. Evans and J. Foster

Alexander Slawik
Northwestern University, USA

Self-Sustained Oscillations in Silicon Microdisks

Silicon microdisks are optical resonators that can exhibit surprising nonlinear behavior. We present a new analysis of the dynamics of these resonators, elucidating the mathematical origin of the spontaneous oscillations and deriving predictions for observed phenomena. Our current work considers the effects of non-constant driving of the resonators and applying the theory of coupled oscillators to a connected grid of microdisk resonators to derive conditions for synchrony and possibly chimera states.
Co-author: D. Abrams

Alejandro Tejedor
St. Anthony Falls Laboratory, USA

Asymmetry in the Evolution of Competing Processes in Networks

We consider a Tokunaga Self-Similar tree network as the underlying structure wherein each branch represents a node and attached branches imply node connectivity. This special class of trees exhibits self-similarity in side branching and has found wide applicability from describing the geometry of real river networks, to biological networks, and the clustering of earthquake aftershocks to name a few. We introduce attack on the network by randomly removing a branch per time step. We show that the Tokunaga tree network exhibits a regime shift in the evolution of network connectivity, which is manifested as a steep drop in the size of the maximum cluster. We simulate recovery after a regime shift by adding the removed branches randomly into the network and show that it results in hysteresis, wherein the evolution of the connectivity of the system behaves differently when the perturbation is increased or decreased. The shift in network connectivity by random attack and recovery not only depends on the degree of node connectivity but also on the underlying network structure. We then consider two reverse processes in the same underlying network and show that their evolution as seen in the points of view of both populations are not symmetric.
Co-authors: A. Longjas, E.Foufoula-Georgiou, and I. Zaliapin

Alan Veliz-Cuba
University of Houston, USA

On the Solution of the Network Inference Problem

The network inference problem consists in reconstructing the topology or wiring diagram of a dynamic network entirely from data. Solving this problem is especially important for gene networks, because in many cases regulation mechanisms are unknown or cannot be detected directly. Even though this problem has been studied in the past, there is no algorithm that guarantees perfect network inference. In this talk we will present a framework and algorithm to solve the network inference problem for discrete networks. Given enough data, the algorithm is guaranteed to reconstruct the wiring diagram of a network with no errors. The framework uses tools from algebraic geometry.

Other Participants

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Thomas S. Bertalan, Princeton University, USA
Daniel Case, Northwestern University, USA
Arnau Gavalda, Northwestern University, USA & Universitat Rovira i Virgili, Spain
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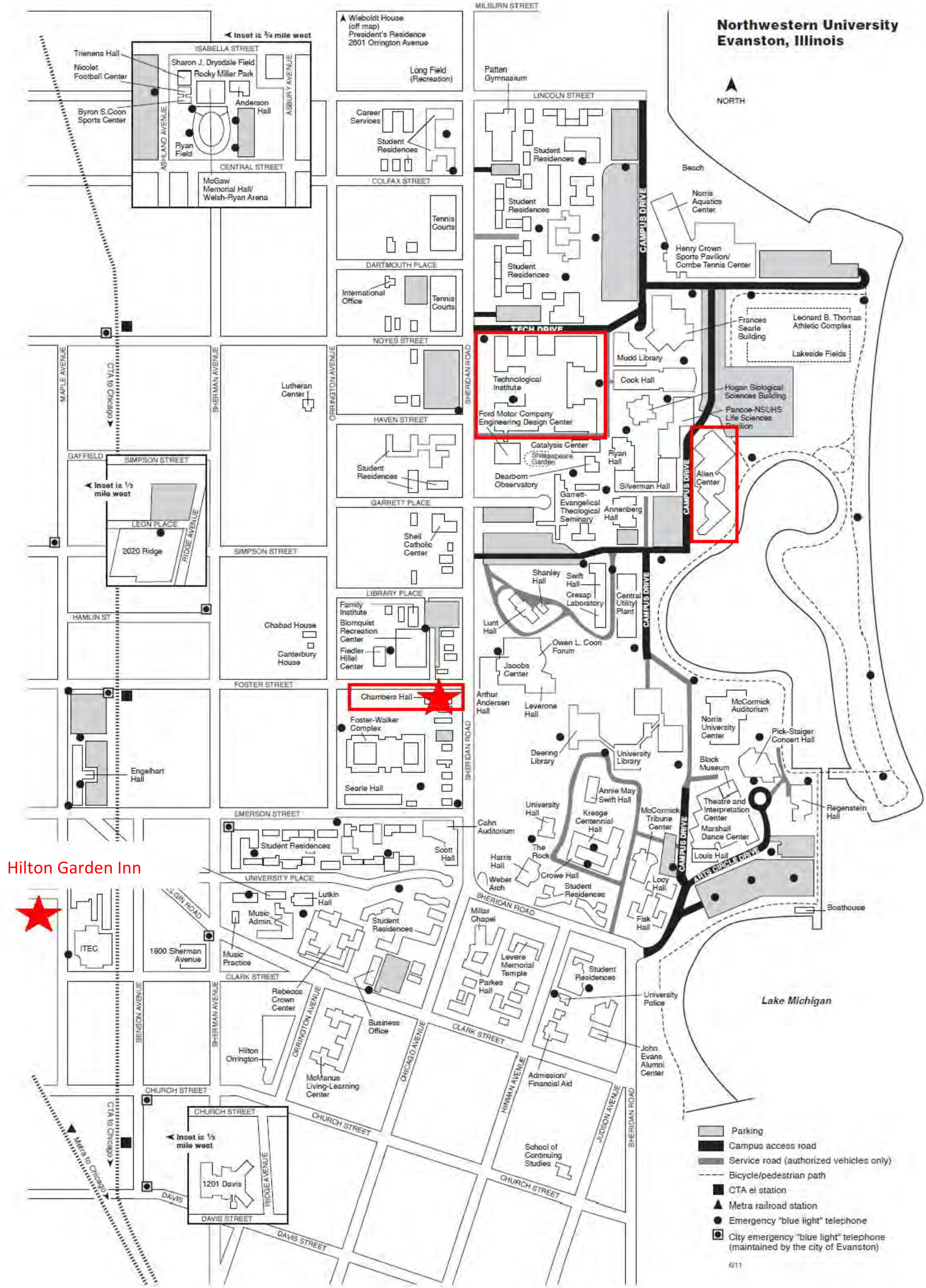
Acknowledgments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Metra railroad station
Emergency "blue light" telephone
City emergency "blue light" telephone (maintained by the city of Evanston)
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